
Weeds in Wheat - Response to Fallow Frequency, Legume Green Manure and Wheat Class

A. Gordon Thomas¹, Julia Y. Leeson¹, Robert P. Zentner², Con A. Campbell³, Fernando Selles²

¹Agriculture and Agri-Food Canada, Saskatoon Research Centre, 107 Science Place, Saskatoon, SK, S7N 0X2; ²Agriculture and Agri-Food Canada, Semiarid Prairie Agricultural Research Centre, Box 1030 Swift Current, SK, S9H 3X2; ³Eastern Cereals and Oilseeds Research Centre, Agriculture and Agri-Food Canada, Ottawa, ON, K1A 0C6

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Introduction

Producers in the semiarid Mixed Grassland ecoregion have traditionally produced spring wheat in fallow-based rotations; however, frequent use of fallow negatively impacts on soil quality. An ongoing experiment was established at Swift Current in 1987 to evaluate management methods and wheat types that may offer wheat producers opportunities to enhance economic returns, while improving environmental sustainability (Zentner et al. 2003). This paper compares the effect of these strategies on weed populations from 1991 to 2002 (12 years).

Experimental Design

Wheat production strategies evaluated include: reducing fallow (F) frequency, using an annual legume green manure (GM) crop as a fallow replacement, adopting a flex-cropping approach based on available water (fallow if dry) or the need to control foxtail barley (fallow if weedy), and planting Canada Western Red Spring wheat (W) versus the higher yielding Canada Prairie Spring wheat class (HY).

The experiment was set up in 1987 as a randomized complete block design with three replicates on the Orthic Brown Chernozem at the Semiarid Prairie Agricultural Research Centre at Swift Current. The experiment included nine rotations. Only seven of the rotations are included in this paper. Each phase of a rotation was present each year. The paper evaluates practices for 12 years from 1991 to 2002. This time period contained four complete cycles for the three-year rotations and three complete cycles for the four-year rotation (Table 1). In the flex-crop rotations, fallow was used twice due to high foxtail barley populations (1994 and 1996) and once due to dry conditions (1992).

The plots were maintained using minimum- to zero-tillage practices (Table 1). 2,4-D was usually applied to all plots in fall. Pre-seeding herbicides were applied in nine years. Spring tillage was used in the other three years. In-crop herbicides for grassy and broadleaf weed control were applied in 11 of 12 years; only a broadleaf herbicide was used in the other year.

Fallows were maintained by herbicides and tillage in eight years and herbicides only in four years. Herbicides or tillage was specifically used in 6.1% of the plot-years (n=423) to control foxtail barley.

Table 1. Fallow Frequency, Tillage Passes and Herbicide Active Ingredient Use from 1991 to 2002.

| Rotations | Fallow Frequency (no. per 12 yrs) | Tillage* | | Herbicides (no. of ai per yr) | |
|----------------|---|----------|-------|----------------------------------|-------|
| | | Fallow | Wheat | Fallow | Wheat |
| F-W-W | 4 | 0.67 | 0.71 | 5.5 | 4.5 |
| F-HY-HY | 4 | 0.67 | 0.67 | 5.4 | 4.5 |
| GM-W-W | 4 | 1.08 | 0.58 | 1.7 | 4.5 |
| F-W-W-W | 3 | 0.67 | 0.61 | 5.3 | 4.6 |
| Cont W (weedy) | 2 | 1.50 | 0.30 | 4.0 | 4.9 |
| Cont W (dry) | 1 | 0 | 0.64 | 8.0 | 4.8 |
| Cont W | 0 | - | 0.50 | - | 4.8 |

* Harrowing and seeding implements were not counted.

Weed Assessments

Weeds were identified and counted in twenty 0.5 m by 0.5 m quadrats per plot before in-crop herbicide was applied (pre-spray) and in late July/early August (residual). Only counts in the wheat phases are included in the analyses.

Changes in the relative abundance of weed species from the pre-spray to residual counts on the site were characterized using a relative abundance index based on frequency, uniformity and density (Thomas 1985). Average density of all weed species in each system was also calculated.

The variance in the weed data attributable to year, spatial patterns and rotation was determined using redundancy analysis (RDA) in the program CANOCO (ter Braak and Šmilauer 1998, Økland 2003). Spatial patterns were defined by replicate block and significant terms of the cubic trend surface (Legendre 1990):

$$z = x + y + x^2 + y^2 + yx^2 + xy^2 + x^3 + y^3$$

Each term on the cubic trend surface was determined for each plot where x is the easting position and y is the northing position of the plot. Each term was entered as a separate variable in the analysis. The forward selection procedure within RDA was used to select significant terms. Only species occurring in more than 3% of the plot-years were included in the RDA. Volunteer crops were not included in the analyses. Prior to the analyses, the densities of all species were log transformed to reduce the influence of plots with species found in relatively high densities. Following convention, the samples were neither centered nor standardized and the species were centered. Rotation was included in the analysis as a set of nominal variables; therefore, the ordinations were scaled to emphasize inter-sample distances. Species scores were divided by standard deviation so that species with large variances do not dominate the ordination.

The significance of the RDA is determined using reduced model Monte Carlo permutation tests. In a Monte Carlo permutation, the species data are randomly assigned to the environmental data (rotation, year, replicate block) 999 times and the RDA is rerun each time. The proportion of times the random data explains more variance in the species data than the original data is used to determine the significance of the factor.

Results and Discussion

The weed populations on the experimental site were dominated by wild buckwheat, pigweed species and green foxtail (Fig. 1). The pigweed species group included redroot, prostrate and tumble, with redroot pigweed being the most abundant species. Subdominant species include stinkweed, Russian thistle, foxtail barley, prostrate knotweed and flixweed. Species relative abundance was similar at the pre-spray and residual counts; however, in-crop herbicide decreased the relative abundance of wild buckwheat and stinkweed. Also, the relative abundance of pigweed species and foxtail barley was higher in residual counts.

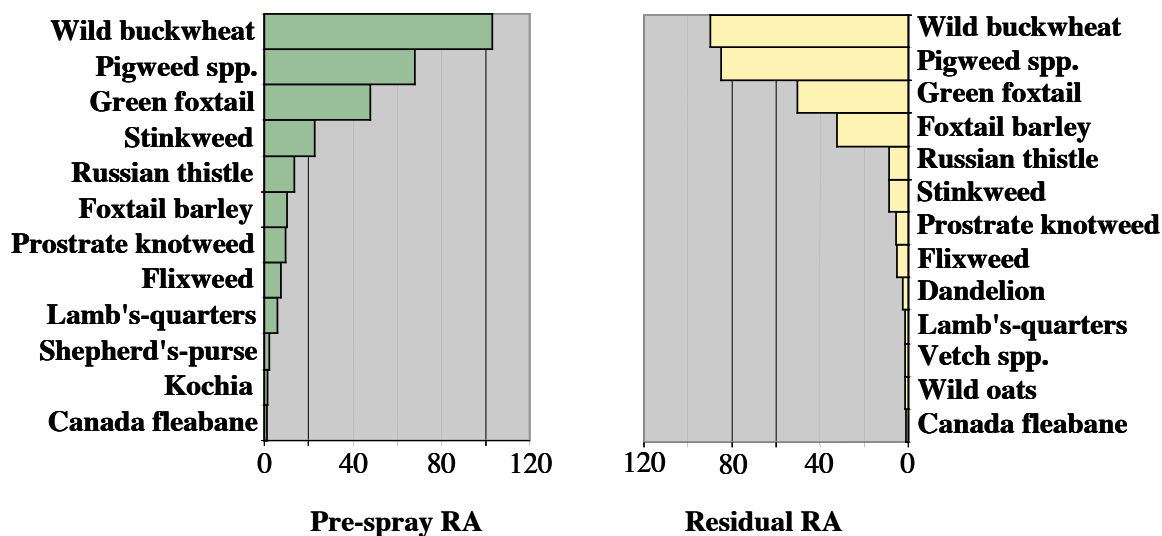


Figure 1. Relative abundance (RA) of weed species occurring in more than 3% of plot-years (n=423) at the time of the pre-spray and residual weed counts. Data are combined for site across rotations and years (1991 to 2002).

The weeds were well managed in all the rotations, with total densities below the average for the area (Fig. 2). However, total densities were lowest in the GM-W-W, Cont W (dry), F-W-W-W and F-W-W. The highest weed densities were observed in the Cont W, Cont W (weedy) and F-HY-HY rotations. In these rotations residual densities were similar to pre-spray densities; while in the other rotations residual densities were significantly less than pre-spray densities.

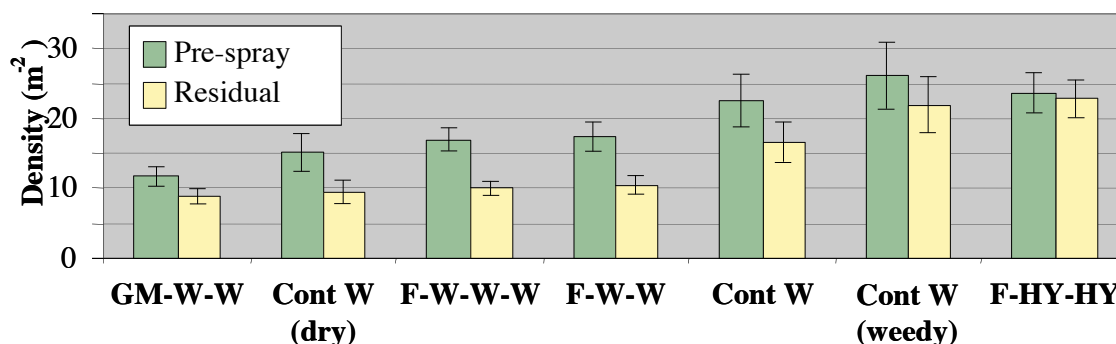


Figure 2. Average density and standard error of weed populations in wheat plots from 1991 to 2002 in each rotation at the time of the pre-spray and residual weed counts.

The majority of the variation in the weed community was attributable to year (Table 2). This variation is likely due to yearly differences in precipitation, temperatures and management. This emphasizes the importance of annual monitoring of weed populations. The relative effect of year was decreased after the in-crop application of herbicides. A large amount of the explained variation was due to the spatial distribution of weeds across the site. This may be attributable to pre-existing seedbank, relative position to external sources of weed seed or differences in soil chemical and physical structure over the plot area. While rotation was able to explain a relatively small percentage of the variation in the weed data, it is still a significant factor. Rotation explains more of the variation in the residual weed data than prior to in-crop herbicide; possibly indicating differing herbicide efficacy between systems.

Table 2. Decomposition of Variation in Weed Densities Presented as Percent of Explained Variance in Pre-Spray and Residual Weed Data.

| Factor | Pre-spray* | | Residual* | |
|----------|--------------------------|-------|--------------------------|-------|
| | % of Explained Variation | P | % of Explained Variation | P |
| Year | 61.7 | 0.001 | 47.1 | 0.001 |
| Spatial | 30.8 | 0.001 | 39.2 | 0.001 |
| Rotation | 7.5 | 0.001 | 13.7 | 0.001 |

*Total variance explained is 53.7% and 48.3% in pre-spray and residual counts, respectively.

RDA of the pre-spray weed data indicates that F-HY-HY and Cont W (weedy) have most green foxtail, pigweed species and Russian thistle (Fig. 3). Longer rotations and high yielding wheat have most foxtail barley and wild buckwheat; however, the inclusion of fallow specifically to control foxtail barley effectively reduced these species. Weed species distinguishing between rotations at the time of the residual weed counts are similar to pre-spray counts (Fig. 4).

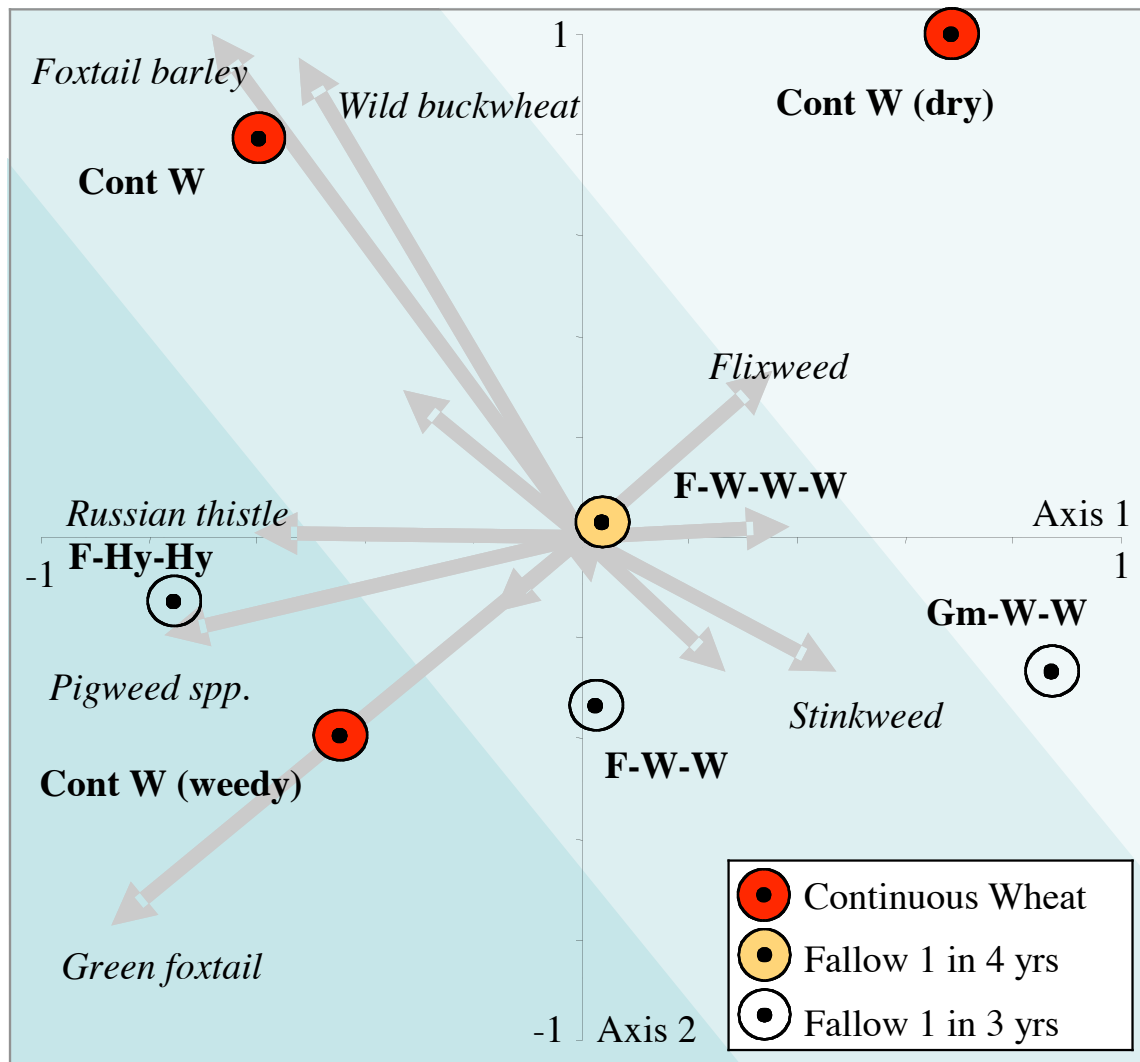


Figure 3. RDA of pre-spray weed densities constrained by rotation. Axis 1 and Axis 2 account for 52% ($P < 0.001$) and 30% ($P < 0.001$) respectively of the variation in the data explained by rotation. Background gradient illustrates green foxtail abundance.

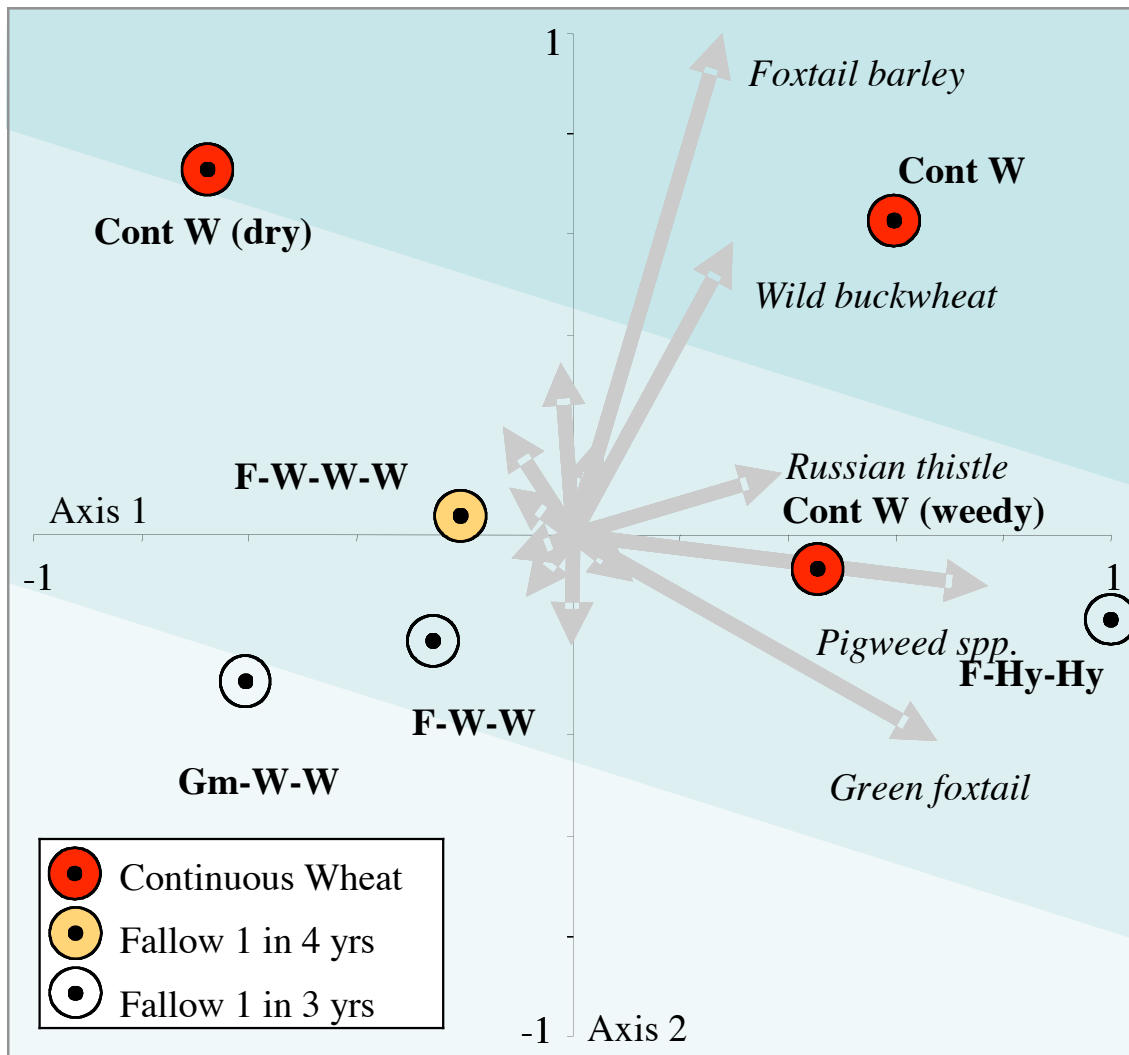


Figure 4. RDA of residual weed densities constrained by rotation. Axis 1 and Axis 2 account for 75% ($P < 0.001$) and 22% ($P < 0.001$) respectively of the variation in the data explained by rotation. Background gradient illustrates foxtail barley abundance.

Implications

Economic analysis indicated that the highest net return was achieved in the continuous wheat rotation, followed by rotations with the least fallow and those with the higher yielding wheat. This indicates that the residual weed populations in these rotations were not high enough to adversely affect yields. Also, the cost associated with occasional changes in management necessitated by high weed populations in some plots did not adversely affect the producers' income.

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